

## Low Profile Lift Apparatus with One to One Direct Lifting Ratio

### BACKGROUND AND SUMMARY OF THE INVENTION

**[0001]** This application claims the benefit of U.S. Provisional Application 60/439,839, filed on January 14, 2003. The disclosure of the above application is incorporated herein by reference.

**[0001]** The present invention relates to a lifting apparatus and a more particularly to a lifting apparatus having a lift platform movable by a pneumatically inflatable spring, air bag, balloon, cushion, hydraulic cylinder, air cylinder or air bellows.

**[0002]** Lift platforms are used to raise and lower various items. In some cases the lift platform is used to lift a person(s) to a level which makes it easier for the person to perform his or her tasks. In other applications a part(s) or other object is placed on the lift platform and the lift platform raises or lowers the height of the part in relation to the operator. By moving the operator(s) or the part(s) to more ergonomic work locations, the efficiency of the operator is increased, the time to complete a given task is generally reduced, and operator's health is maintained by minimizing stress and strain of the human body during the job task.

**[0003]** The prior art shows many differently configured hydraulic and pneumatic lift mechanisms. One such lift is shown in US Patent 3,994,474 and includes two parallel-configured sides plates moved by an air spring (air bag). US Patent 6,286,812 shows another lifting platform which uses a scissors-type of linkage which is movable by an inflatable bag.

**[0004]** The present invention is configured to move the lift platform in an essentially parallel manner relative to the base without using scissors or folding linkages (as shown in the prior art) while employing a lift mechanism movable in a generally upward direction to minimize the force needed to lift an object, part or

person. Experience has shown this approach also reduces the cost of the lift apparatus in relation to scissor lifting mechanism. The present invention utilizes a one-to-one direct, vertical lift ratio which provides an improved system. In the context of an air spring a one-to-one direct lifting ratio relates to the way in which the air spring dynamic load force vectors are applied during the lifting cycle such that for every unit of measure the lift platform raises during the lifting cycle the air spring travels the same unit of measure. The vertical loads are transferred directly through the air spring to the floor level or support structure.

**[0005]** One of the advantages of the present invention is the lift (and its components) can be lowered to an very low profile (and subsequently raised) which accommodates a wider range of operator statures to enable, where desired, to place the platform so the work piece is in the neutral posture range of the human body commonly referred to as the knuckle-to-elbow range.

**[0006]** One embodiment of the present invention uses a lift mechanism in the form of a parallelogram linkage which is moved by an air spring. The top of the air spring is fixed to the underside of the lift platform and by virtue of the flexibility of the air spring and the parallelism of the linkage, the air spring is able to follow the longitudinal movement of the platform.

**[0007]** It is an object of the present invention to provide to a lift platform with improved ergonomically characteristics which permit an increase in operator efficiency and a decrease in operator injury.

**[0008]** Accordingly the invention comprises: a lifting apparatus comprising: one of a mobile or stationary base; a lift platform having a geometric first center, the lift platform movable relative to the base from a lowered position to an upper position; a linkage or linkage mechanism interconnecting the base and the lift platform for guiding the lift platform to remain in a generally mutually parallel relationship with the base. The base, lift platform and linkage are configured so that when the lift platform in its lowered position the center of the lift platform intersects the base at a first point and with the lift platform in its upper position the center

intersects the base at a second point which is longitudinally off-set from the first point. The lifting apparatus also includes a fluid (in general liquid or pneumatic) spring operatively mounted between the lift platform and the base, for controllably lifting and lowering the lift platform. Single and multi-chambered air springs are described as well as two, three and four bar linkage mechanisms and various control mechanisms are provided to control the movement of the lift platform.

**[0009]** Many other objects and purposes of the invention will be clear from the following detailed description of the drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0010]** FIGURE 1 is a side view of a lift apparatus in accordance with the present invention.

**[0011]** FIGURE 1a shows a lift platform of the present invention in a lower position than shown in FIGURE 1.

**[0012]** FIGURE 1b shows an alternate embodiment of the invention with a movable base structure.

**[0013]** FIGURE 2 illustrates an isometric view of the lift apparatus of FIGURE 1.

**[0014]** FIGURE 3 is a top plan view of a lift apparatus.

**[0015]** FIGURE 4 is a diagrammatic top view of a base support structure.

**[0016]** FIGURE 5 shows an exemplary hinge configuration.

**[0017]** FIGURE 6 is a cross-sectional view of an inflatable device using two air springs.

**[0018]** FIGURE 6a shows a deflated air spring device.

**[0019]** FIGURE 6b shows an air spring with wheel slide connection to the platform.

**[0020]** FIGURE 6c shows an alternate embodiment of the present invention.

- [0021]** FIGURE 6d shows a square air bellows.
- [0022]** FIGURE 6e shows a round air bellows, cloth, rubber or vinyl bag.
- [0023]** FIGURE 6f shows an alternate pillow construction.
- [0024]** FIGURE 7 diagrammatically shows an air control system.
- [0025]** FIGURE 8 is a view of another embodiment of the invention with a rotary platform.
- [0026]** FIGURE 9 shows a bushing or bearing for use with the embodiment of FIGURE 8.
- [0027]** FIGURE 10 is a side view of another embodiment of the invention with a tilt assembly.
- [0028]** FIGUREs 11 – 13 show another embodiment of the invention.
- [0029]** FIGUREs 14 – 16 show another embodiment of the invention.
- [0030]** FIGUREs 17 – 20 show other embodiments of the invention for lifting humans, for lifting boxes, an embodiment using a protective skirting to prevent operator injury and other embodiment configured as an automotive lift

#### DETAILED DESCRIPTION OF THE DRAWINGS

**[0031]** The reference is made to Figures 1 through 5 which illustrate a first embodiment of the present invention. More particularly, the figures illustrate to a lift apparatus 20 comprising a lift platform 30, and a support structure 40 having a base 42. The lift platform 30 and the support structure 40 are connected by a linking or stabilizing mechanism (linkage) 50. To the lift platform 30 and the support structure 40 are also connected by a lift spring which in the preferred embodiment is an inflatable device 60 which moves the platform 30 and linking or stabilizing mechanism 50 relative to the structure 40.

**[0032]** In the preferred embodiment of the Figures 1 - 3 the lift platform 30 is made of a tubular steel (or steel plate) construction comprising a plurality of interconnected tubes, bars or ribs to 30a to 30e. The tubes or ribs may be hollow or

solid. Tubes, bars or ribs 32a and 32b are arranged in opposing pairs and form sides 132a and 132b of the platform 30. Tubes, bars or ribs 32c and 32b form opposite sides 132c and 132d of the platform 30. Optional tubes, bars or ribs 32e and 32f can be used to reinforce the tubes (bars or ribs) 32c and 32d. As can be seen the tubes (bars or ribs) 32a-f form an open support with an opening 33. The opening 33 can be closed by a plate 34 (or tubing or railing) which is secured to the bottom of the tubes. Those parts used to close or at least fill in the opening 33 can also be secured to the top of the tubes (bars or ribs) as well.

**[0033]** As can be appreciated the use of thin wall tubes (bars, ribs) will reduce the weight of the platform. Alternatively, the tubes or ribs can be replaced by a plate of appropriately material (such as steel, plastic, etc.). For example, a solid thickness of material or a plate of a honeycombed construction can be use.

**[0034]** The base 42 comprises a plurality of inter-connected flat plates 42a-42d. Alternatively a large size plate with cut-outs can be substituted to achieve a unitary construction. The plate or plates 42a-42d can be connected together such as by welding. FIGURE 4 is an isolated view of the base 42 and plates 42a-d. The base 42 can be configured to be permanently mounted or mounted to a movable fixture 41 such as one having wheels or coasters 43 as shown in FIGURE 1b in contrast to Figure 1 which shows the base 42 secured to an adjacent floor 46. To achieve this mounting arrangement of FIGURE 1, one or more the plates include a one or more openings 44 to receive a corresponding fastener 44a enabling the support structure 40 to be fastened (screwed, bolted, riveted) to the adjacent floor 46 (if desired). The fasteners 44a can be inserted through the openings 44 into the floor or alternatively the fasteners 44a can be pre-positioned to extend up from the floor 46 wherein the base 42 is placed about these pre-positioned fasteners. Another fastener such as a washer (not shown) is attached to the extending fastener thereby securing a corresponding plate to the floor. For example, a work object including a box which may include parts is positioned atop the platform 30.

**[0035]** The linkage or linkage mechanism 50 in the preferred embodiment comprises a plurality of bars 152 –158 and top hinges 162, 164, 166 and 168 and bottom hinges 172, 174, 176 and 178 respectively configured as a parallelogram bar linkage. Other variants can be used with the present invention as illustrated in subsequent figures.

**[0036]** Reference is briefly made to Figure 5 which illustrates an exemplary hinge 172 as well as the interconnection of bar 152, hinge 172 and the base 42. The relationship of the bars 152 – 158 to the top or upper hinges is the same or similar. The illustrated hinge/bar interconnection is relatively straightforward. Each hinge such as 172 comprises a tubular member 180 (opening 181) adapted to be fixedly secured to the base 42 (or platform 30 as the case may be) and another interfitting tubular member 182, with opening, slot or passage 183, fixed to or made as a part of an end of a bar such as 152 and which rotates with the bar. The tubular members 180 and 182 can be fixed to the base and to the platform by welding or other known techniques. Each hinge such as 172 further includes a pin 184 that interconnects the hinge parts 180 and 182 and provides a hinge or pivot axis and which fits within opening, slot or passage 143.

**[0037]** Reference is again made to FIGURES 1 and 2 which show axes 190, 192 and 194. Axis 190 runs along the underside of the platform 30 and defines the location of the upper hinges 162 and 164 which are located at outboard corners of the platform along axis 190. Axis 192 is displaced a distance  $d_1$  away from axis 190 in a direction toward axis 194. Axis 194 extends through the geometric center of the lift platform 30. Hinges 166 and 168 are located on axis 194 at sides 132c and 132d of the platform 30. Hinge 166 is secured to the bottom of tubes 32c and 32f while hinge 168 is secured to the bottom of tubes 32d and 32e. To accommodate the length of both hinge parts 180 the platform may include shortened lengths of tubing 32g and 32h to which the upper hinges 166 and 168 are also secured.

**[0038]** FIGURE 1 shows the lift platform 30 at its extended height  $h_1$ . This orientation is useful in defining the location of the lower hinges 176 and 178 on the base. A lower hinge axis 196 (for hinges 172 and 174) is located in the base a distance  $d_2$  away from and parallel to axis 190. A second lower hinge axis 198 (for hinges 176 and 178) is located in the base a distance  $d_1$  behind and parallel to axis 196.

**[0039]** The bars 152 – 158 and hinge locations, in the preferred embodiment, are configured to minimize floor space as the lift platform 30 is raised and lowered as well as to provide and improved mechanical advantage.

**[0040]** As mentioned above the apparatus 20 also includes a lift spring such as an inflatable lift device or mechanism 60. FIGURE 6 shows further details of the one such lifting device. In the preferred embodiment the lift device 60 includes a plurality of interconnected inflatable springs 262, 262a. One such spring is made by Herkules Hebetchnik GmbH as part number 300-001. Each air spring can be made from a generally non-permeable material including an elastomer such as molded rubber; extruded film or sewn-together fabric or reinforced fabric construction depending on the environment and size of the objects to be placed on the lift. Each spring 262, 262a includes a flexible side part formed as an, elastomeric ring 264 having a cylindrically shaped, flexible wall 266. The wall is configured to include an upper opening 268 and a lower opening 270. Each spring includes an upper, circular mounting plate 280 sealed in a fluid tight manner to the wall 266 (ring 262) about the upper opening 268. A lower, circular mounting plate 282 is also sealed in a fluid tight manner to the wall 266 at the lower opening 270.

**[0041]** As illustrated in FIGURE 6 the present invention uses two interconnected springs 262 and 262a (configurations with more than two interconnected air springs are within the contemplation of the invention). The lower plate 282 of upper spring 262 and the upper plate 280 of the lower spring 262a each include an aligned opening 286 with interior threads. A, hollow, threaded the fastener 284 (having threads 284a) is received through the aligned openings 286

and secures the above plates together. The lower plate 282 of spring 262a can be secured to the base 42 in a similar way with another fastener 284a' of similar construction. Each fastener includes a central passage 284b to permit air flow therethrough.

**[0042]** In the preferred embodiment the diameter  $D_s$  of the inflated spring 262 is about 640 mm and the inflated height  $H_s$  is about 69 mm. The lowered height of the spring, at zero pressure is about 69mm.

**[0043]** The diameter  $D_m$  of the mounted plated 280 and 282 are about 510 mm. With these dimensions it has been found that the two inflatable springs 262 and 262a, when compressed and deflated will nest into one another as illustrated in FIGURE 6a. One of the benefits of being able to nest the springs 262 and 262a is the platform can be lowered to about 100 mm cm above the base 42. FIGURE 6 schematically shows a source of compressed air C, connected to the opening 284b in the lower of the fasteners 284' located through the base 42 (and lower plate 282). The air supply connection can be by way of discrete pressure lines 265 (flexible or stiff or solid) or for example of a pressure line or passage integrally formed in the base 42. FIGURE 6 shows, in phantom line, an alternate connection of pressure line 265 communicating the source of pressure gas or fluid) C to the upper plate of air spring 262. As can be appreciated, pressurized fluid can be communicated to and through the wall of the spring 260 or 262a as schematically illustrated in phantom line by air connector 285.

**[0044]** Reference is made to FIGURE 1a which shows the platform 30 in a lowered condition: FIGURE 1a also superimposes, in phantom line, the platform 30 (with some of the bars) in a raised condition for purpose of comparison. FIGURE 1a shows a portion of spring 60 in its lowered or compressed configuration and FIGURE 6a shows a cross-sectional view of the compressed spring 60.

**[0045]** The center of the upper plate 280 of spring 262 is located so its geometric center is below the geometric center of the platform 30 as defined by axis 194. In one embodiment of the invention the upper spring 262 is physically



connected to the platform 30 (including being connected to plate 34) by bolting the plate 34 and the upper plate 280 together. It is also within the scope of the present invention that plate 280 of the upper spring 280 and the platform 30 and more particular the plate 34 are relatively movable one to the other. This can be achieved simply by permitting the upper plate 280 to press upwardly (devoid of a bolted or other fixed securement) on the lower surface of plate 34 and as the platform moves (vertically and longitudinally as defined by the linkage 50) the plate 34 and the spring plate 280 will slide, in a longitudinal direction (for example front-to-back) relative to one another. FIGURE 6b shows a rudimentary wheel slide assembly 300 comprising a frame 290 and plurality of support wheels 291 fixed to plate 280 which slidingly support plate 34 of the lift platform 30.

**[0046]** Reference is made to point A of Figure 1. Point A is used to define the location of the lower spring 262a. Point A is achieved conceptually by permitting the linkage 50 to completely rotated counter-clockwise which will effectively place the platform 30 on top of the support structure 40. In this position upper hinges 162 and 164 (as well as the entire platform 30) will move along an arc, see line 267, (defined by the length of bars 152 and 154 (the length of all of the bars is the same). Point A is essentially the intersection of the upper hinges with the structure 40. Distance d3 is the linear distance between point A and the lower hinge 178 (or 176) location. The lower spring 262a, that is, the center of the lower plate 282 of spring 262a, is located left-to-right generally about one-half the distance d3 and centered laterally below the upper spring 262 (see Figure 6). Point B as well as axis 220 show the center of the lower spring 262a.

**[0047]** Reference is made to phantom line 230 which traces the trajectory (as visible in a side view) of the center of the lift platform 30, as can be appreciated as the lift platform 30 and the linkage 50 move up and down the center of the lift platform will follow this arc (which defines the longitudinal motion of the platform). If the top of the inflatable device 60 is hard-mounted to the platform 30 and the bottom of the inflatable device is also hard mounted to the support structure 40, the lift

apparatus 60 must be sufficiently flexible so it can follow the relative movement of the lift platform 30. This relative movement of the inflatable device 60, in the preferred embodiment, is accomplished by using the low profile design of the Herkules air springs 262 and 262a. The relative movement can be accomplished with one air spring (see FIGURE 6c) or a stack or plurality of springs (see FIGURES 6d) or single cell springs shown in Figures 6e and 6f. This flexibility of the device 60 also assures the resultant upward force vector produced by the inflatable device 60 always acts vertically on the platform as well as acts on the platform providing an increased mechanical efficiency and direct one-to-one lift ratio.

**[0048]** Reference is briefly made to FIGURE 6c which diagrammatically shows an inflatable device 60' comprising a single chambered, cylindrical air spring 262'. The air spring 262' also uses the mounting plates 280 and 282. Lower plate 282 can be mounted to the base 42 (not shown) and to a source of compresses air C. Plate 280 would be mounted to the lift platform 30. As shown in FIGUE 6d, the inflatable device 60a can be configured as a bellows with a plurality of accordion folds 262b formed along an exterior of the bellows such as along a rectangular side wall. Figure 6e shows another embodiment of a single, circular-annular air spring 60c made in two halves of elastomeric material joined along a central or equatorial seam or bead 61. The spring includes a respective opening 268 and 270 on its top and bottom for received of a respective upper and lower plate 280 and or 282.

**[0049]** FIGURE 6f shows another embodiment of the invention. In this embodiment the air spring 60b which includes two facing panels 460 and 462 of reinforced material joined sewn or bonded at a non-permeable seam 464. Such material can for example be a) a plastic film or b) woven fabric covered with a non-permeable coated such as silicon, neoprene or the like.

**[0050]** Reference is made to FIGURE 7 which diagrammatically shows a control system such as a manually controlled fluid valve 240 for inflating and deflating the device 60 (springs 262, 262a, 262'). The control system 240 includes a source of pressurized or compressed gas 242 which is communicated to a manually

controllable air valve 244 via an air line 246. The valve 244 is communicated to an inlet of the lift device 60 through another air line 245 (in one of the ways mentioned above). The valve 244 is movable between positions corresponding to Fill (F), Hold (H), and Exhaust (E). With the valve 244 placed in the Fill position pressured air is received by the inflatable device 60 through air line 245 and the lift platform will be lifted to a new work position. When the operator has moved the platform to the new work position, the valve is moved to its Hold position in which the air pressure in the device 60 is maintained. The lift platform can be lowered if the valve 244 is moved to the Exhaust position which enables the inflation air within the device 60 to be released through exhaust port 247 and the platform lowered. A more sophisticated air control system can be achieved by adding a pressure sensor 250 which is connected in a closed loop manner (through a closed loop controller 251 in a known manner) can automatically control the internal pressure within the device 60. The controller 251 is diagrammatically shown in FIGURE 7. Similarly, a height or position sensor 252 can be added in a closed loop manner and enables the lift platform to maintain a determinable height regardless of the loads placed on the lift platform 30. In a control loop control system a command pressure or command position such as the height of the platform is input to the controller 251 and the achieved pressure and or height signal is fed back to the controller 251 to generate an error signal which controls the inflatable device.

**[0051]** Reference is made to FIGURES 8 and 9 which shows another alternate of the present invention. The apparatus 20' of FIGURE 8 is identical to apparatus 20 but includes an upper plate 254 which serves as a work table or upper platform. In the embodiment shown the dimension of plate 254 is about the same as lift platform 30 (or plate 34, if used, however, plate 254 can be over-sized extending considerably beyond the dimensions of the lift platform 30. FIGURE 9 shows an exemplary rotary bearing or bushing 256 rotatably connecting the plates 254 and 34. In this embodiment the plat or platform 254 can be manually rotated by the operator to place to items thereon to a more convenient or ergonomic working position.

**[0052]** Reference is made to FIGURE 10 which illustrates an alternate embodiment of the invention. This embodiment also includes an additional plate of such as plate 310. Plate of 310 is attached to the lift apparatus 20 using one or more hinges 312. Plate 310 additionally includes a crank mechanism 314 which can be manual or automatic. The manual mechanism includes a crank handle 316 connected through a transmission 315 to a rotatable rod 317. Rotation of the rod 317 caused a block 322 to translate along the rod (in the manner of a worm gear mechanism). A rear support or link 318 (which extends from hinge 320) is connected to the movable block 322. As the handle crank is turned the plate 310 (in essence moves with block 322) and rotates from a lower position shown by phantom line 310a to a more up right position also shown in phantom line as 310b, which may vary between 0 and 90 degrees. One of the benefits of this type of system is work pieces secured to the rotatable plate 310 can be moved to more ergonomic positions.

**[0053]** Reference is made to FIGURES 11 – 13 which show another embodiment of the invention. FIGURE 11 is an isometric view of lift apparatus 20". FIGURE 12 is a top view and FIGURE 13 is a top view of the base 42' of the support platform 40'. The lift apparatus 20" incorporates many of the elements of apparatus 20, the major difference being the relative placement of the bars 156, 158, upper hinges 166, 168 and lower hinges 176, 178. Tubes, bars or ribs 32a and 32b are placed interior to the cross-bars 32e and 32f and the hinges 166 and 168 have been moved to the remote ends of tubes 32c,f and 32e,d respectively. Axis 192 is shown, as before extending between the upper hinges 166 and 168. Axis 198 which defines the location of the complementary lower hinges 176 and 178 has been moved a like distance to maintaining the parallelism of the four bars 152, 154, 156 and 158. As can be seen in FIGURE 13 the base plates 42a-d are arranged differently than in FIGURE 4 but are still configured to be placed on the work floor. The fasteners 44a can be placed in any or all of the various plates 42a-d. FIGURE 13 also shows a bar 330 which extends into the center of the lower air spring 262a. The bar 330 is

hollow and functions as high speed and secure air passage 332 comprising of a thin wall tubing with a rectangular cross-section. Numeral 334 illustrates an air fitting to which an air hose can be connected. Numeral the 336 (see FIGURE 13) shows an exit port located beneath the air bag spring 262a through which air is communicated to the air spring.

**[0054]** FIGURES 14 – 16 shown another variation of the present invention. The basic difference in comparison to the embodiment of FIGURE 11 is that bar 158, upper hinge 168 and lower hinge 178 have been removed and upper hinge 166 has been moved to the center of tube 32b. Bar 156 and lower hinge 176 extend from the upper hinge to maintain the parallelism with the other bars 152 and 154. The base 42a" is made of fewer plates than is base 42'. Hinge 176 is secured to a remote end of base plate 42a".

**[0055]** FIGURE 17 shows yet another embodiment of the present invention. In this embodiment two identical lift mechanisms 20 (20',20") are positioned relative to one another. A large rectangular platform 354 bridges the distance between the lift mechanisms 20. Pneumatic air lines for each air spring 60 extend from a common pneumatic controller 356. In this configuration platform 354 can be raised and lower in a horizontal configuration. In this embodiment in the platform 354 his raised and lower to move a worker 358 relative to his workstation (not shown).

**[0056]** FIGURE 18 illustrates another embodiment which is usable with each of the lift mechanisms described above. In this embodiment a palette 360 has been positioned on the lift platform 30. A plurality of boxes (generally stackable parts 362) are stacked upon the palette 360 and movable vertically.

**[0057]** FIGURE 19 shows another variant of the present invention. In this embodiment a protective housing is generally shown as 370 located about any of the lift mechanism 20, 20', etc discussed above. The housing includes with a flexible bellows shaped skirting 372 formed with a plurality of accordion pleats. The skirting moves up and down with the movement of the lift mechanism. For the purpose of

illustration, to show the usefully of the present invention an open wire frame storage box 374 has been placed upon the lift mechanism.

**[0058]** Figure 20 illustrates a lift mechanism 20 positioned below a vehicle 380. The lift mechanism 20 is configured as a jacket or vertical hoist for this vehicle 380.

**[0059]** Many changes and modifications in the above-described embodiment of the invention can, of course, be carried out without departing from the scope thereof. Accordingly, that scope is intended to be limited only by the scope of the appended claims.